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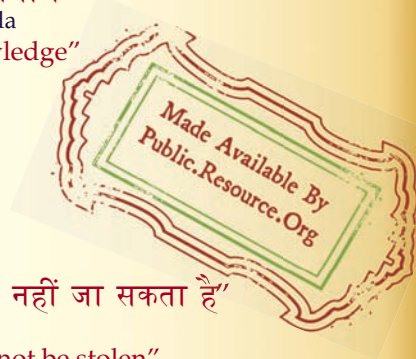
IS 4749 (1974): Method for Calculation of Bulk Quantities of Industrial Aromatic Hydrocarbons [PCD 1: Methods of Measurement and Test for Petroleum, Petroleum Products and Lubricants]



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“Knowledge is such a treasure which cannot be stolen”

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Indian Standard
METHOD FOR CALCULATION
OF BULK QUANTITIES OF INDUSTRIAL
AROMATIC HYDROCARBONS
(*First Revision*)

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Indian Standard

METHOD FOR CALCULATION OF BULK QUANTITIES OF INDUSTRIAL AROMATIC HYDROCARBONS

(*First Revision*)

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Indian Standard

METHOD FOR CALCULATION OF BULK QUANTITIES OF INDUSTRIAL AROMATIC HYDROCARBONS

(*First Revision*)

0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 6 November 1974, after the draft finalized by the Coal Carbonization Products Sectional Committee had been approved by the Chemical Division Council.

0.2 Since the values of coefficients of expansion for aromatic hydrocarbons are higher than those for petroleum products, it had been found necessary to evolve this standard covering the method of calculation of bulk quantities of benzene, toluene, xylenes and ethylbenzene, as distinct from IS : 2164-1961*.

0.3 This standard was first published in 1968. The tabulated values of volume reduction factors for benzene, toluene, xylenes and ethylbenzene in the standard were up to a temperature of 45°C. As storage temperatures for aromatic hydrocarbons were found to go up due to higher ambient temperature or other reasons, it was felt necessary to extend these tables up to 55°C which would cover the temperature variations observed. Accordingly, in this revision, Tables 1 to 4 have been extended up to 55°C. Adoption of these extended tables will help proper implementation of this standard.

0.4 The Indian Standards on tank calibration, gauging, sampling, temperature measurement and determination of density have laid down procedures which, when followed, allow the volume, temperature and density of bulk quantities of aromatic hydrocarbons to be determined with considerable precision. The care with which these physical measurements have been made will be largely nullified if the subsequent calculations are carried out inaccurately or incorrectly. The quantity calculated will be substantially correct if:

a) The accepted† volume is substantially correct. This implies that:

1) The container has been accurately calibrated and its calibration table correctly computed by recognized methods. For

*Method for calculation of bulk quantities of petroleum and liquid petroleum products.

† 'Accepted' means 'the figure taken into further calculation'.

vertical and horizontal tanks, the recommendations laid down in the following standards shall apply:

IS : 2007-1961 Method for calibration of vertical oil storage tanks,

IS : 2008-1961 Method for computation of capacity tables for vertical oil storage tanks,

IS : 2009-1961 Method for calibration of horizontal and tilted oil storage tanks, and

IS : 2166-1963 Method for computation of capacity tables for horizontal and tilted oil storage tanks.

- 2) The liquid depth has been correctly measured and recorded by the methods laid down in IS : 1518-1960*.
- b) The container has been correctly sampled in accordance with IS : 1447-1966†.
- c) The accepted liquid temperature is substantially correct and has been obtained in accordance with the recommendations laid down in IS : 1519 (Part I)-1961‡.
- d) All densities have been determined in accordance with the method for determination of density laid down in IS : 1448 [P : 16]-1967§.

0.4 The methods of calculation given in this standard have, therefore, been drawn up to give the maximum possible accuracy in the final calculated quantities compatible with the precision of the physical measurements.

0.5 In reporting the result of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960||.

1. SCOPE

1.1 This standard prescribes the method of calculation of bulk quantities of benzene, toluene, xylenes and ethylbenzene (of purity 95 percent by mass and above) and assumes that the impurities consist of those normally present in conventional commercial products.

*Method for gauging of petroleum and liquid petroleum products.

†Methods of sampling of petroleum and its products.

‡Method for temperature measurement of petroleum and its products, Part I.

§Methods of test for petroleum and its products: P 16 Density by hydrometer method (first revision).

||Rules for rounding off numerical values (revised).

2. TERMINOLOGY

2.1 For the purpose of this standard, the following definitions shall apply.

2.1.1 Accepted Temperature — It is the temperature reading which is taken for further calculation, the temperature being measured as prescribed in IS : 1519 (Part I)-1961*. However, if the initial and final temperatures of the aromatic hydrocarbon before and after the movement are different, the accepted temperature shall be the weighted average of these two temperatures, the masses being based on the estimated volumes of liquid before and after its movement.

2.1.2 Gross Measured Volume — It is the total volume of liquid in a container for a given dip or gauge and at the observed temperature at the time of gauging.

2.1.3 Net Measured Volume — It is the gross measured volume at the accepted temperature after deducting any free water and sediment which may be present.

2.1.4 Net Quantity Received or Delivered — It is the difference between the net volume or net mass of clean aromatic hydrocarbon, before and after the material movement for each container under consideration.

2.1.5 Net Volume of Clean Aromatic Hydrocarbon at the Accepted Temperature — It is the net measured volume of aromatic hydrocarbon at the accepted temperature, less the quantity of any water and sediment in suspension in the material.

2.1.6 Net Volume of Clean Aromatic Hydrocarbon at Standard Reference Temperature — It is the measured volume of aromatic hydrocarbon, reduced to standard reference temperature of 15°C by means of appropriate tables given in this standard, less the quantity of any water and sediment in suspension in the aromatic hydrocarbon.

2.1.7 Standard Reference Temperature — 15°C.

SECTION I METHODS FOR NORMAL CALCULATIONS

3. GENERAL

3.1 The final quantity of aromatic hydrocarbon may be required in terms of mass in air, volume at standard reference temperature, or for some purposes, volume at the accepted temperature. All these requirements involve a knowledge of the volume of aromatic hydrocarbon in a container.

*Method for temperature measurement of petroleum and its products, Part I.

3.2 When several containers are involved, the quantity of aromatic hydrocarbon in each container shall be separately calculated and the final quantity shall be recorded by adding the separate quantities so obtained by following the procedures laid down in this standard. For the purpose of measurement, pipelines shall be taken into consideration. Pipelines do not lend themselves to simple methods of measurements and are most conveniently dealt with either completely empty or completely full, although with full pipelines some correction for difference in temperature before and after aromatic hydrocarbon movement may be necessary. Pipelines are dealt with separately in Section 2.

4. INTERPRETATION OF REPORTED MEASUREMENTS

4.1 Measurements Reported — Gauging reports shall give all relevant details of tank number or numbers, the position and number of dip hatches, product, date, time, etc. The gauger's note shall, in addition, contain the following information:

- a) *Dip or Ullage (With Height of Reference Point Above the Datum Point)* — The dip or ullage shall be taken as prescribed in IS : 1518-1960* from the dip hatch specified in the tank calibration table.
- b) *Temperature* — It shall be middle or the average of upper, middle and lower temperatures as prescribed in IS : 1519 (Part I)-1961 †.
- c) *Water Dips* — Water dips shall be taken as prescribed in IS : 1518-1960* from the dip hatch specified in the tank calibration table but where incomplete water bottoms are encountered, dips shall be reported from more than one dip hatch if the tank is so fitted.
- d) *Sludge* — If sludge is present at the bottom of the tank, the gauger may report this by an ullage measurement or by a measurement in accordance with appropriate Indian Standard, if present.

4.2 In addition to the information given in 4.1 the following information shall be required:

- a) Measured density at the observed temperature; and
- b) Percentage of water or sediment, if any.

4.3 Preliminary Calculations — Before the final calculations of aromatic hydrocarbon quantities are commenced, it may be necessary to adjust the reported measurements in order to obtain correct (true) figures, namely, the determination of true dip or ullage.

*Method for gauging of petroleum and liquid petroleum products.

†Method for temperature measurement of petroleum and its products, Part I.

4.3.1 Determination of True Dip or Ullage — The true dip or ullage is that which is taken from the dip hatch specified in the tank calibration table and will be the dip or ullage normally reported. Exceptions to this are:

- a) when tank bottom movement is suspected. The method of calculating aromatic hydrocarbon volume under these circumstances is treated separately under 11; and
- b) where the dip or ullage reported from the dip hatch specified in the tank calibration table shows that the aromatic hydrocarbon level is below the level of the first entry in the tank calibration table. The volume of aromatic hydrocarbon under these circumstances shall be determined as specified in 10.

4.3.2 Determination of Average Dip — The average dip, where required, shall be determined by the following procedure:

- a) If the tank is fitted with a central dip hatch and a number of peripheral dip hatches, first compute the arithmetic means of the dips at the central dip hatch and at each peripheral dip hatch taken in pairs. The average dip for the tank is then the sum of these arithmetic means divided by the number of arithmetic means so computed.
- b) If the tank is fitted with a central dip hatch, n peripheral dip hatches and n intermediate hatches situated midway between the centre and the periphery of the tank, the average dip is $\frac{1}{3n} (n \times \text{central dip} + \text{the sum of all the non-central dips})$.
- c) If the tank is fitted with peripheral dip hatches only, the average dip of the tank is the arithmetic mean of the dips at all dip hatches.
- d) In all other cases, make the best possible estimate of the average dip of the tank from the dips at all dip hatches, making due allowance for the relative positions of the dip hatches.

4.3.3 Determination of True Water Dip — The true water dip is that which is taken from the dip hatch specified in tank calibration table, and will be the water dip normally reported. Exceptions to this are:

- a) when tank bottom movement is suspected. The method of calculating water volumes under these circumstances is treated separately in 11.2; and
- b) where the water dip reported shows that the water level is below the level of the first entry in the tank calibration table. The volume of water under these circumstances shall be determined as specified in 10.

4.3.4 Determination of True Quantity of Sludge or Sediment at the Bottom of a Tank — When the level of sludge or sediment at the bottom of a tank has been determined by ullage measured at the dip hatch specified in the tank calibration table, the level so reported will normally be the level at which the tank calibration table will be entered.

If, however, the level so reported is below the level of the first entry in the tank calibration table, then the levels of sludge or sediment shall be measured from all the dip hatches fitted to the tank and an average of these levels obtained by the procedure specified in 4.3.2. The volume of sludge or sediment represented by this average shall be determined as specified under 10.

4.3.5 Determination of Accepted Temperature — The accepted temperature of the aromatic hydrocarbon in a tank shall be the middle temperature of the liquid in the tank or average of the upper, middle and lower temperatures, as the case may be.

4.3.6 Determination of Accepted Density — The accepted density of the aromatic hydrocarbon in a tank shall be the density determined on a composite sample prepared in accordance with IS : 1447-1966*.

4.3.7 Determination of True Percentage of Water and Sediment in Suspension — Where percentages of water and sediment in suspension have been reported on more than one sample, the true percentage of water and sediment in suspension shall be determined by calculating the average percentage, due allowance being given to the approximate quantity of aromatic hydrocarbon represented by each sample on which the percentage has been determined.

5. CALCULATION OF VOLUME AT THE ACCEPTED TEMPERATURE

5.1 Gross Measured Volume Before Movement

5.1.1 Obtain from the calibration table for the tank the volume corresponding to the true dip (*see* 4.3.1), interpolating or using the proportional parts table where this is available, if necessary.

5.1.2 Where ullages are given and the calibration table for the tank has been compiled on aromatic hydrocarbon depth basis, first convert the ullage to equivalent dip by deducting the ullage from the known distance between the ullage reference point and the dipping datum point.

5.1.3 Where ullages are given and if the tank calibration table is compiled on the ullage basis, proceed as in 5.1.1.

*Methods of sampling of petroleum and its products.

5.2 Volume of Water, Sludge and Sediment

5.2.1 Obtain from the calibration table for the tank the volume of free water and sediment corresponding to the true water dip before aromatic hydrocarbon movement, interpolating or using the proportional parts table where this is available, if necessary.

5.2.2 Where water or sediment or both measurements are given as ullages and the tank calibration table has been compiled on aromatic hydrocarbon depth basis, convert the ullages to equivalent dips as in 5.1.2 before entering the tank calibration table.

5.2.3 Where the tank calibration table is entered against ullage, convert the true water dip to equivalent ullage by procedure given in 5.1.2.

5.2.4 Where water or sediment or both measurements are given as ullages and the tank calibration table has been compiled on an ullage basis, proceed as in 5.1.1.

5.3 Net Measured Volume Before Movement — To obtain the net measured volume of aromatic hydrocarbon in a tank before movement, deduct from the gross measured volume before movement as measured in 5.1, the volume of free water, sludge and sediment before movement as in 5.2.

5.4 Net Volume of Clean Aromatic Hydrocarbon Before Movement

5.4.1 To obtain the net volume of clean aromatic hydrocarbon at accepted temperature in a tank before movement, deduct from the net measured volume before movement obtained as in 5.3, the true water and sediment in suspension present in the aromatic hydrocarbon.

5.4.2 Where contracts make an allowance for suspended water and sediment, deduct from the net measured volume before movement the difference between the true and allowable quantity of suspended water and sediment.

5.5 Gross Measured Volume After Movement — Use procedure similar to that prescribed in 5.1.

5.6 Volume of Water, Sludge and Sediment After Movement — Use procedure similar to that prescribed in 5.2.

5.7 Net Measured Volume After Movement — Use procedure similar to that prescribed in 5.3.

5.8 Net Volume of Clean Aromatic Hydrocarbon After Movement — Use procedure similar to that prescribed in 5.4.

6. CALCULATION OF VOLUME AT STANDARD REFERENCE TEMPERATURE (15°C)

6.1 Calculation of Volume Reduction Factor (VRF)

6.1.1 Factors to reduce any measured volume of benzene or toluene at the ambient temperature to that at 15°C may be calculated as follows:

$$VRF = \frac{\text{Density (in vacuo) at temperature } t \text{ (} Dt \text{)}}{\text{Density (in vacuo) at } 15^{\circ}\text{C}}$$

Dt for benzene or toluene may be obtained from the following formula:

$$Dt = a + bt + ct^2$$

where

t = temperature in °C; and

a , b and c are constants.

For benzene:

$a = 0.899\,744\,4$, $b = -0.001\,021\,5$, and $c = -0.000\,000\,716\,69$

For toluene:

$a = 0.885\,420\,1$, $b = -0.000\,923$, and $c = 0$

6.1.1.1 Tables 1 and 2 give VRF s for benzene and toluene respectively. These values do not change although densities of commercial benzene or toluene at 15°C may vary within a narrow range and are valid for benzene or toluene of purity 95 percent or above. A sample calculation for VRF at 26°C for benzene is given below to illustrate the method of computing these values:

$$\begin{aligned} VRF \text{ at } 26^{\circ}\text{C} &= \frac{0.899\,744\,4 - 0.001\,021\,5 \times 26 - 0.000\,000\,716\,69 \times 26^2}{0.899\,744\,4 - 0.001\,021\,5 \times 15 - 0.000\,000\,716\,69 \times 15^2} \\ &= 0.986\,927\,1 \text{ rounded off to } 0.986\,93 \text{ in Table 1.} \end{aligned}$$

6.1.2 Volume reduction factors for xylene may be correlated to temperature by the following general formula:

$$VRF = A + Bt + Ct^2$$

where

t is observed temperature in °C; and

A , B and C are constants the values of which for different isomers of xylene are as follows:

Isomer	A	B	C
Mixed and <i>m</i> -xylene	1.014 460	-0.000 956 2	-0.000 000 518 4
<i>o</i> -xylene	1.014 173	-0.000 942 9	-0.000 000 129 6
<i>p</i> -xylene	1.014 815	-0.000 983 1	-0.000 000 303 7

6.1.2.1 The values for *VRFs* for isomers of xylene and mixed xylenes, calculated from the above formula, are given in Table 3.

6.1.3 Density *D* of ethylbenzene at a temperature *t* is given by the following formula:

$$Dt = a + bt + ct^2$$

where

t = temperature in °C,

a = 0.884 24,

b = -0.000 844, and

c = -0.000 000 5.

6.1.3.1 The formula for calculating volume reduction factors for ethylbenzene is arrived at as follows:

$$\begin{aligned} VRF &= \frac{Dt}{D_{15}} = \frac{0.884\ 24 - 0.000\ 844\ t - 0.000\ 000\ 5\ t^2}{0.871\ 47} \\ &= 1.014\ 653 - 0.000\ 963\ 5\ t - 0.000\ 000\ 57\ t^2 \end{aligned}$$

6.1.3.2 The values for *VRFs* and densities calculated from the above formulae are given in Table 4.

6.2 Calculation of Net Volumes at 15°C Received or Delivered

6.2.1 Calculate the net volume of benzene, toluene, xylenes or ethylbenzene at 15°C before movement by multiplying the net measured volume of benzene, toluene, xylenes or ethylbenzene at accepted temperature obtained in 5.3 by the volume reduction factor corresponding to the accepted temperature as given in Table 1, 2, 3 or 4 whichever is applicable.

6.2.2 Calculate the net volume at 15°C after movement similarly.

6.2.3 The difference of volumes as calculated in 6.2.1 and 6.2.2 is the net volume at 15°C received or delivered.

7. CALCULATION OF MASS

7.1 Mass of Aromatic Hydrocarbon Before or After Movement —

To obtain the mass, of clean aromatic hydrocarbon in a tank before or after movement, multiply the net volume before or after movement at standard temperature of 15°C with corresponding measured density before or after movement at 15°C corrected for buoyancy of air (from Table 5).

7.2 Mass of Aromatic Hydrocarbon Received or Delivered

This is obtained by calculating the difference of the masses in the tank before and after movement, calculated as described in 7.1.

TABLE 1 VOLUME REDUCTION FACTORS TO 15°C FOR BENZENE

(Clause 6.1.1.1)

OBSERVED TEMPERATURE °C	VOLUME REDUCTION FACTOR	OBSERVED TEMPERATURE °C	VOLUME REDUCTION FACTOR
(1)	(2)	(1)	(2)
10.0	1.005 88	28.0	0.984 53
10.5	1.005 30	28.5	0.983 93
11.0	1.004 71	29.0	0.983 33
11.5	1.004 12	29.5	0.982 72
12.0	1.003 53	30.0	0.982 12
12.5	1.002 95	30.5	0.981 52
13.0	1.002 36	31.0	0.980 92
13.5	1.001 77	31.5	0.980 31
14.0	1.001 18	32.0	0.979 71
14.5	1.000 59	32.5	0.979 11
15.0	1.000 00	33.0	0.978 51
15.5	0.999 41	33.5	0.977 90
16.0	0.998 82	34.0	0.977 30
16.5	0.998 23	34.5	0.976 69
17.0	0.997 64	35.0	0.976 09
17.5	0.997 05	35.5	0.975 48
18.0	0.996 46	36.0	0.974 87
18.5	0.995 86	36.5	0.974 26
19.0	0.995 27	37.0	0.973 66
19.5	0.994 68	37.5	0.973 05
20.0	0.994 08	38.0	0.972 44
20.5	0.993 49	38.5	0.971 83
21.0	0.992 89	39.0	0.971 23
21.5	0.992 29	39.5	0.970 62
22.0	0.991 70	40.0	0.970 01
22.5	0.991 11	40.5	0.969 39
23.0	0.990 51	41.0	0.968 78
23.5	0.989 91	41.5	0.968 17
24.0	0.989 32	42.0	0.967 56
24.5	0.988 72	42.5	0.966 95
25.0	0.988 12	43.0	0.966 34
25.5	0.987 52	43.5	0.965 72
26.0	0.986 93	44.0	0.965 11
26.5	0.986 33	44.5	0.964 50
27.0	0.985 73	45.0	0.963 89
27.5	0.985 13	45.5	0.963 27

(Continued)

TABLE 1 VOLUME REDUCTION FACTORS TO 15°C FOR BENZENE — *Contd*

OBSERVED TEMPERATURE °C	VOLUME REDUCTION FACTOR	OBSERVED TEMPERATURE °C	VOLUME REDUCTION FACTOR
(1)	(2)	(1)	(2)
46.0	0.962 66	51.0	0.956 49
46.5	0.962 04	51.5	0.955 87
47.0	0.961 42		
47.5	0.960 81	52.0	0.955 25
48.0	0.960 19	52.5	0.954 63
48.5	0.959 58	53.0	0.954 01
49.0	0.958 96	53.5	0.953 39
49.5	0.958 34		
50.0	0.957 72	54.0	0.952 77
50.5	0.957 11	54.5	0.952 14
		55.0	0.951 52

TABLE 2 VOLUME REDUCTION FACTORS TO 15°C FOR TOLUENE

(Clause 6.1.1.1)

OBSERVED TEMPERATURE °C	VOLUME REDUCTION FACTOR	OBSERVED TEMPERATURE °C	VOLUME REDUCTION FACTOR
(1)	(2)	(1)	(2)
10.0	1.005 30	18.0	0.996 82
10.5	1.004 77	18.5	0.996 29
11.0	1.004 24	19.0	0.995 76
11.5	1.003 71	19.5	0.995 23
12.0	1.003 18	20.0	0.994 70
12.5	1.002 65	20.5	0.994 18
13.0	1.002 12	21.0	0.993 65
13.5	1.001 59	21.5	0.993 12
14.0	1.001 06	22.0	0.992 59
14.5	1.000 53	22.5	0.992 06
15.0	1.000 00	23.0	0.991 53
15.5	0.999 47	23.5	0.991 00
16.0	0.998 94	24.0	0.990 47
16.5	0.998 41	24.5	0.989 94
17.0	0.997 88	25.0	0.989 41
17.5	0.997 35	25.5	0.988 88

(Continued)

TABLE 2 VOLUME REDUCTION FACTORS TO 15°C FOR
TOLUENE — *Contd*

OBSERVED TEMPERATURE °C	VOLUME REDUCTION FACTOR	OBSERVED TEMPERATURE °C	VOLUME REDUCTION FACTOR
(1)	(2)	(1)	(2)
26.0	0.988 35	41.0	0.972 47
26.5	0.987 82	41.5	0.971 94
27.0	0.987 29	42.0	0.971 41
27.5	0.986 76	42.5	0.970 88
28.0	0.986 23	43.0	0.970 35
28.5	0.985 70	43.5	0.969 82
29.0	0.985 17	44.0	0.969 29
29.5	0.984 64	44.5	0.968 76
30.0	0.984 12	45.0	0.968 23
30.5	0.983 59	45.5	0.967 70
31.0	0.983 06	46.0	0.967 17
31.5	0.982 53	46.5	0.966 64
32.0	0.982 00	47.0	0.966 11
32.5	0.981 47	47.5	0.965 58
33.0	0.980 94	48.0	0.965 05
33.5	0.980 41	48.5	0.964 52
34.0	0.979 88	49.0	0.963 99
34.5	0.979 35	49.5	0.963 46
35.0	0.978 82	50.0	0.962 93
35.5	0.978 29	50.5	0.962 40
36.0	0.977 76	51.0	0.961 88
36.5	0.977 23	51.5	0.961 35
37.0	0.976 70	52.0	0.960 82
37.5	0.976 17	52.5	0.960 29
38.0	0.975 64	53.0	0.959 76
38.5	0.975 11	53.5	0.959 23
39.0	0.974 58	54.0	0.958 70
39.5	0.974 05	54.5	0.958 17
40.0	0.973 53	55.0	0.957 64
40.5	0.973 00		

TABLE 3 VOLUME REDUCTION FACTORS TO 15°C FOR XYLENES

(Clause 6.1.2.1)

OBSERVED TEMPERATURE °C	VOLUME REDUCTION FACTOR		
	Mixed and <i>m</i> -Xylene	<i>o</i> -Xylene	<i>p</i> -Xylene
(1)	(2)	(3)	(4)
10·0	1·004 85	1·004 73	—
10·5	1·004 36	1·004 26	—
11·0	1·003 88	1·003 79	—
11·5	1·003 39	1·003 31	—
12·0	1·002 91	1·002 84	—
12·5	1·002 43	1·002 37	—
13·0	1·001 96	1·001 89	—
13·5	1·001 46	1·001 42	—
14·0	1·000 97	1·000 95	—
14·5	1·000 49	1·000 47	—
15·0	1·000 00	1·000 00	1·000 00
15·5	0·999 51	0·999 53	0·999 50
16·0	0·999 03	0·999 05	0·999 01
16·5	0·998 54	0·998 58	0·998 51
17·0	0·998 05	0·998 11	0·998 01
17·5	0·997 57	0·997 63	0·997 52
18·0	0·997 08	0·997 16	0·997 02
18·5	0·996 59	0·996 68	0·996 52
19·0	0·996 10	0·996 21	0·996 03
19·5	0·995 62	0·995 74	0·995 53
20·0	0·995 13	0·995 26	0·995 03
20·5	0·994 64	0·994 79	0·994 53
21·0	0·994 15	0·994 31	0·994 04
21·5	0·993 66	0·993 84	0·993 54
22·0	0·993 17	0·993 37	0·993 04
22·5	0·992 68	0·992 89	0·992 54
23·0	0·992 19	0·992 42	0·992 04
23·5	0·991 70	0·991 94	0·991 54

(Continued)

TABLE 3 VOLUME REDUCTION FACTORS TO 15°C FOR XYLENES — *Contd*

OBSERVED TEMPERATURE °C	VOLUME REDUCTION FACTOR		
	Mixed and <i>m</i> -Xylene	<i>o</i> -Xylene	<i>p</i> -Xylene
(1)	(2)	(3)	(4)
24.0	0.991 21	0.991 47	0.991 05
24.5	0.990 72	0.990 99	0.990 55
25.0	0.990 23	0.990 52	0.990 05
25.5	0.989 74	0.990 04	0.989 55
26.0	0.989 25	0.989 57	0.989 05
26.5	0.988 76	0.989 09	0.988 55
27.0	0.988 26	0.988 62	0.988 05
27.5	0.987 77	0.988 14	0.987 55
28.0	0.987 28	0.987 67	0.987 05
28.5	0.986 79	0.987 19	0.986 55
29.0	0.986 29	0.986 72	0.986 05
29.5	0.985 80	0.986 24	0.985 55
30.0	0.985 31	0.985 77	0.985 05
30.5	0.984 81	0.985 29	0.984 55
31.0	0.984 32	0.984 82	0.984 05
31.5	0.983 82	0.984 31	0.983 55
32.0	0.983 33	0.983 87	0.983 04
32.5	0.982 84	0.983 39	0.982 55
33.0	0.982 34	0.982 92	0.982 05
33.5	0.981 84	0.982 44	0.981 54
34.0	0.981 35	0.981 97	0.981 04
34.5	0.980 85	0.981 49	0.980 54
35.0	0.980 36	0.981 01	0.980 03
35.5	0.979 86	0.980 54	0.979 53
36.0	0.979 36	0.980 06	0.979 03
36.5	0.978 87	0.979 58	0.978 53
37.0	0.978 37	0.979 11	0.978 02
37.5	0.977 87	0.978 63	0.977 52
38.0	0.977 37	0.978 16	0.977 02
38.5	0.976 88	0.977 68	0.976 51
39.0	0.976 38	0.977 20	0.976 01
39.5	0.975 88	0.976 73	0.975 51

(Continued)

TABLE 3 VOLUME REDUCTION FACTORS TO 15°C FOR XYLENES — *Contd*

OBSERVED TEMPERATURE °C	VOLUME REDUCTION FACTOR		
	Mixed and <i>m</i> -Xylene	<i>o</i> -Xylene	<i>p</i> -Xylene
(1)	(2)	(3)	(4)
40.0	0.975 38	0.976 25	0.975 00
40.5	0.974 88	0.975 77	0.974 50
41.0	0.974 38	0.975 30	0.974 00
41.5	0.973 88	0.974 82	0.973 49
42.0	0.973 38	0.974 34	0.972 99
42.5	0.972 88	0.973 86	0.972 48
43.0	0.972 38	0.973 39	0.971 98
43.5	0.971 88	0.972 91	0.971 47
44.0	0.971 38	0.972 43	0.970 97
44.5	0.970 88	0.971 96	0.970 46
45.0	0.970 38	0.971 48	0.969 96
45.5	0.969 88	0.971 00	0.969 46
46.0	0.969 38	0.970 53	0.968 95
46.5	0.968 88	0.970 05	0.968 44
47.0	0.968 37	0.969 57	0.967 94
47.5	0.967 87	0.969 09	0.967 43
48.0	0.967 37	0.968 62	0.966 93
48.5	0.966 86	0.968 14	0.966 42
49.0	0.966 36	0.967 66	0.965 91
49.5	0.965 86	0.967 18	0.965 41
50.0	0.965 35	0.966 70	0.964 90
50.5	0.964 85	0.966 23	0.964 39
51.0	0.964 35	0.965 75	0.963 89
51.5	0.963 84	0.965 27	0.963 38
52.0	0.963 34	0.964 79	0.962 87
52.5	0.962 83	0.964 31	0.962 37
53.0	0.962 33	0.963 84	0.961 86
53.5	0.961 82	0.963 36	0.961 35
54.0	0.961 31	0.962 88	0.960 84
54.5	0.960 81	0.962 40	0.960 33
55.0	0.960 30	0.961 92	0.959 83

TABLE 4 VOLUME REDUCTION FACTORS TO 15°C FOR
ETHYLBENZENE

(Clause 6.1.3.2)

OBSERVED TEMPERATURE °C	VOLUME REDUCTION FACTOR	OBSERVED TEMPERATURE °C	VOLUME REDUCTION FACTOR
(1)	(2)	(1)	(2)
10.0	1.004 91	28.0	0.987 09
10.5	1.004 42	28.5	0.986 59
11.0	1.003 94	29.0	0.986 08
11.5	1.003 44	29.5	0.985 59
12.0	1.002 95	30.0	0.985 08
12.5	1.002 45	30.5	0.984 58
13.0	1.001 99	31.0	0.984 08
13.5	1.001 48	31.5	0.983 58
14.0	1.000 99	32.0	0.983 07
14.5	1.000 49	32.5	0.982 57
15.0	1.000 00	33.0	0.982 06
15.5	0.999 51	33.5	0.981 57
16.0	0.999 01	34.0	0.981 07
16.5	0.998 52	34.5	0.980 56
17.0	0.998 03	35.0	0.980 07
17.5	0.997 53	35.5	0.979 55
18.0	0.997 04	36.0	0.979 05
18.5	0.996 55	36.5	0.978 54
19.0	0.996 05	37.0	0.978 04
19.5	0.995 55	37.5	0.977 53
20.0	0.995 05	38.0	0.977 03
20.5	0.994 56	38.5	0.976 52
21.0	0.994 06	39.0	0.976 01
21.5	0.993 56	39.5	0.975 50
22.0	0.993 07	40.0	0.975 00
22.5	0.992 58	40.5	0.974 49
23.0	0.992 07	41.0	0.973 99
23.5	0.991 58	41.5	0.973 47
24.0	0.991 08	42.0	0.972 97
24.5	0.990 58	42.5	0.972 46
25.0	0.990 09	43.0	0.971 94
25.5	0.989 58	43.5	0.971 44
26.0	0.989 09	44.0	0.970 93
26.5	0.988 58	44.5	0.970 42
27.0	0.988 09	45.0	0.969 91
27.5	0.987 58	45.5	0.969 38

(Continued)

**TABLE 4 VOLUME REDUCTION FACTORS TO 15°C FOR
ETHYLBENZENE — Contd**

OBSERVED TEMPERATURE °C	VOLUME REDUCTION FACTOR	OBSERVED TEMPERATURE °C	VOLUME REDUCTION FACTOR
(1)	(2)	(1)	(2)
46.0	0.968 89	51.0	0.963 77
46.5	0.968 38	51.5	0.963 25
47.0	0.967 87	52.0	0.962 73
47.5	0.967 36	52.5	0.962 23
48.0	0.966 84	53.0	0.961 71
48.5	0.966 33	53.5	0.961 20
49.0	0.965 82	54.0	0.960 68
49.5	0.965 31	54.5	0.960 17
50.0	0.964 79		
50.5	0.964 28	55.0	0.959 65

TABLE 5 BUOYANCY CORRECTION DATA FOR DENSITY

(Clause 7.1)

DENSITY AT 15°C IN VACUO	CORRECTION*
(1)	(2)
kg/l	kg/l
0.82	0.001 098
0.83	0.001 097
0.84	0.001 095
0.85	0.001 094
0.86	0.001 092
0.87	0.001 091
0.88	0.001 090
0.89	0.001 088
0.90	0.001 087

*To be subtracted.

8. EXAMPLE OF NORMAL CALCULATIONS

8.1 Delivered Volume at Standard Reference Temperature of 15°C Where 'Before Movement' Temperature Differs from 'After Movement' Temperature — The following calculations illustrate the recommended procedure for determining the volume at 15°C and mass of benzene delivered when the 'before delivery' and 'after delivery' temperatures are different:

a) *Gauging Data:*

	<i>Before Loading</i>	<i>After Loading</i>
True gross dip, cm	920.6	311.2
True water dip, cm	7.0	7.0
True average temperature, °C	26	28

b) *Laboratory Data:*

Measured density at 26°C, kg/l (in vacuo)	0.871	0.871
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c) *Calculation of Net Volume at Standard Reference Temperature:*

Gross measured volume (from tank calibration table), litres	13 809 000	4 668 000
Volume of free water (from tank calibration table), litres	105 000	105 000
Net measured volume, litres	13 704 000	4 563 000
Volume reduction factor (from Table 1)	0.986 93	0.984 53

$$\therefore \text{Net volume of benzene delivered at 15°C, litres} = 13\,524\,889 - 4\,492\,410 \\ = 9\,032\,479$$

d) *Calculation of Net Mass of Benzene Delivered:*

$$\begin{aligned} \text{Density of benzene (in vacuo) at 15°C, kg/l} &= \frac{\text{Measured density (in vacuo) at 26°C}}{\text{Volume reduction factor (Table 1)}} \\ &= \frac{0.871}{0.986\,93} \\ &= 0.882\,5 \end{aligned}$$

Buoyancy correction = $-0.001\ 098$
(Table 5)

∴ Density at 15°C in air, kg/l = $0.881\ 4$

Net volume of benzene = $9\ 032\ 479$
delivered at 15°C [see
8.1 (c)], litres

∴ Net mass of benzene = $9\ 032\ 479 \times 0.881\ 4$
delivered, kg
= $7\ 961\ 227$

SECTION 2 METHODS FOR SPECIAL CALCULATIONS

9. GENERAL

9.0 The special calculations and modifications to the normal calculations specified in Section 1 are given in this section for products under certain given conditions.

10. TANKS WITH UNCALIBRATED IRREGULAR BOTTOMS

10.1 If the aromatic hydrocarbon or water dip in a tank is below the first entry in the calibration table, dips shall be taken at all the dip hatches, and an average dip calculated as described in 4.3.2. The quantity represented by this average dip is then calculated using the l/cm at the first entry in the tank calibration table.

11. TANK BOTTOM MOVEMENT

11.1 The overall height of the dip hatch above the bottom datum point in a tank may change owing to tank bottom movement. This change will not normally affect the calculation of any quantity of aromatic hydrocarbon in a tank or quantity of aromatic hydrocarbon moved, if the datum point is fully covered by the aromatic hydrocarbon or water before and after movement.

11.2 Where an incomplete water or no water bottom exists or the aromatic hydrocarbon level is below the datum point, as shown by dips taken at all the dip hatches on the tank, both gross dips and water dips, if any, shall be averaged before entering the tank calibration table. The method of averaging these dips is the same as that given in 4.3.2. The quantities represented by these dips are read from the calibration table and taken for further calculations.

12. LIQUID IN PIPELINES

12.1 For the purpose of calculating the quantity of aromatic hydrocarbon contained in them, pipelines shall be regarded as separate containers. The total capacity of the pipeline shall be calculated by a sound mathematical method, or by means of tables giving the capacity per unit length. In calculating the total quantity of aromatic hydrocarbon movement, the difference in the quantities contained in the pipelines before and after the movement is added to or subtracted from quantities received into or delivered from the tanks, as the case may be. For stock quantity purposes, the quantities contained in the pipelines are added to the relevant stock in the tank or tanks.

13. LIQUID IN FLOATING ROOF TANKS

13.1 When the roof is freely floating, a quantity equivalent to the roof displacement shall be deducted from the measured quantity corresponding to the gauge taken.

13.2 The following formula may be used to calculate the quantity equivalent to the roof displacement:

$$V = \frac{M}{P}$$

where

V = volume in litres equivalent to the roof displacement,

M = mass in kg of floating roof, and

P = density in kg/l of product at standard reference temperature.

13.3 When the roof is not in a freely floating position, the proportionate fractional displacement due to the floating roof is to be deducted from the measured volume. This displacement will be obtained from the supplementary tables provided with the tank calibration tables. Since this cannot be calculated accurately, it is suggested to keep the roof always in a floating position.

13.4 Where the aromatic hydrocarbon level is low and does not touch the roof, no deduction is to be made for the roof mass, as the roof rests on its supports.

13.5 The following example illustrates the recommended procedure for calculating the quantity of benzene in a floating roof tank:

Data

True gross dip, cm	= 810.6
True water dip, cm	= 8.2

Temperature of benzene in tank, °C	= 26.0
Measured density of benzene (in vacuo) at 26°C, kg/l	= 0.871
Mass of floating roof, kg	= 85 214

Calculations

Gross measured volume corresponding to dip, litres	= 8 916 600
Volume of free water, litres	= 90 200
∴ Net measured volume of benzene at 26°C before accounting for roof displacement, litres	= 8 826 400
Volume reduction factor (from Table 1)	= 0.986 93
∴ Net measured volume at 15°C before accounting for roof displacement, litres	= 8 711 039
Density of benzene (in vacuo) at 15°C, kg/l	= $\frac{\text{Density (in vacuo) at 26°C}}{0.986\ 93}$
	(By definition of Table 1)
	= $\frac{0.871}{0.986\ 93}$
	= 0.882 5
Buoyancy correction factor (Table 5)	= 0.001 098
∴ Density in air at 15°C, kg/l	= 0.882 5 - 0.001 09
	= 0.881 4
Volume of benzene at 15°C equivalent to roof displacement, litres	= $\frac{85\ 214}{0.881\ 4}$
	= 96 680
∴ Net volume of benzene at 15°C, litres	= 8 711 039 - 96 680
	= 8 614 359

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14. VOLUME AT 15°C WHEN MASS DATA ARE AVAILABLE

14.1 When quantities of benzene (or toluene) are directly weighed, the corresponding volume at 15°C may be found as under:

$$\begin{aligned} \text{Mass of benzene delivered,} &= 25\,420 \\ &\text{kg} \\ \text{Measured density of benzene} &= 0.871 \\ &\text{at } 26^{\circ}\text{C in vacuo, kg/l} \\ \therefore \text{Density of benzene at } 15^{\circ}\text{C} &= 0.881\,4 \\ &\text{in air, kg/l [see 8.1 (d)]} \\ \therefore \text{Volume of benzene at} &= \frac{25\,420}{0.881\,4} \\ 15^{\circ}\text{C, litres} &= 28\,840 \end{aligned}$$

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